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# Variation of infrarenal aortic diameter: A necropsy study

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***Purpose:*** **To determine anatomicomorphological changes in the infrarenal portion of the abdominal aorta, we performed 645 dissections of the segment in corpses undergoing necropsy.**

***Methods:*** **The aortas were removed from the corpses with a surgical technique; by means of a device that we designed, the external diameter of the artery was measured after luminal pressure was reestablished. This way, it was possible to avoid underestimation of the arterial diameter postmortem. The influence of age, sex, body size, arterial hypertension, chronic obstructive pulmonary disease, and coronary disease on the aortic diameter and the influence of different degrees of sclerosis on the infrarenal aorta wall were analyzed. Considering the diameters, aortas were regarded as "normal" when they did not present any ectasia, arteriomegaly, aneurysm, or hypoplasia.**

***Results:*** **The sample involved 645 subjects whose ages ranged from 19 to 97 years (mean age, 55.8 years). Of the 645 subjects, 65.5% (423) were men, 34.5% (222) were women, 81% (523) were white, and 19% (122) were of another race. The diameters of arteries showing no anomalous dilatation (ectasis, arteriomegaly, or aneurysm) varied according to subject age, sex, body length, and the degree of atherosclerosis on the aorta wall ($P < .01$). Aortic diameters of those subjects with arterial hypertension, coronary disease, and chronic obstructive pulmonary disease were compared with the aortic diameters of control subjects, and significant differences were not shown ($P > .05$). Twenty-nine aneurysms were found (4.5% prevalence). Four were ruptured aneurysms, and all occurred in aortas with diameters larger than 5.0 cm.**

***Conclusion:*** **The infrarenal aortic diameter enlarges with aging, and this enlargement occurs earlier in men than in women. Those subjects who had a longer body length and advanced sclerosis on the aorta wall had larger aortic diameters. There was a high prevalence of infrarenal aneurysms (4.5%), with rupture found solely in aortas with diameters larger than 5.0 cm. (J Vasc Surg 1999;29:920-7.)**

Aortic aneurysms develop most often in the infrarenal area of the abdominal aorta (80% of aortic aneurysms are infrarenal[1]). This segment may undergo other changes, which are also anomalous and related to the arterial diameter, such as ectasis, arteriomegaly, and hypoplasia. According to several studies,[2-8] other factors, such as age, sex, body length, and systemic affections, may also determine morphometric variations.

Although image diagnostic methods become more accurate every day, studies relying on necropsy findings still are an important source for medical knowledge, particularly those intending to clear anatomicomorphological features. Values are underestimated in relation to the postmortem analysis of the arterial diameter, because the aorta is found with no arterial pressure.[9]

By recomposing the arterial diameter with a device that distends the vessel wall and partially restores the forces acting on it, variations in the diameter of the infrarenal abdominal aorta were analyzed, in a random sample of corpses submitted to necropsy.

## METHODS

Corpses studied were necropsied for clearing of the cause of death between 1992 and 1995 at the Department of Pathology of the School of Medicine of the University of São Paulo. This department performs necropsies on the bodies of those who died of nonviolent causes.

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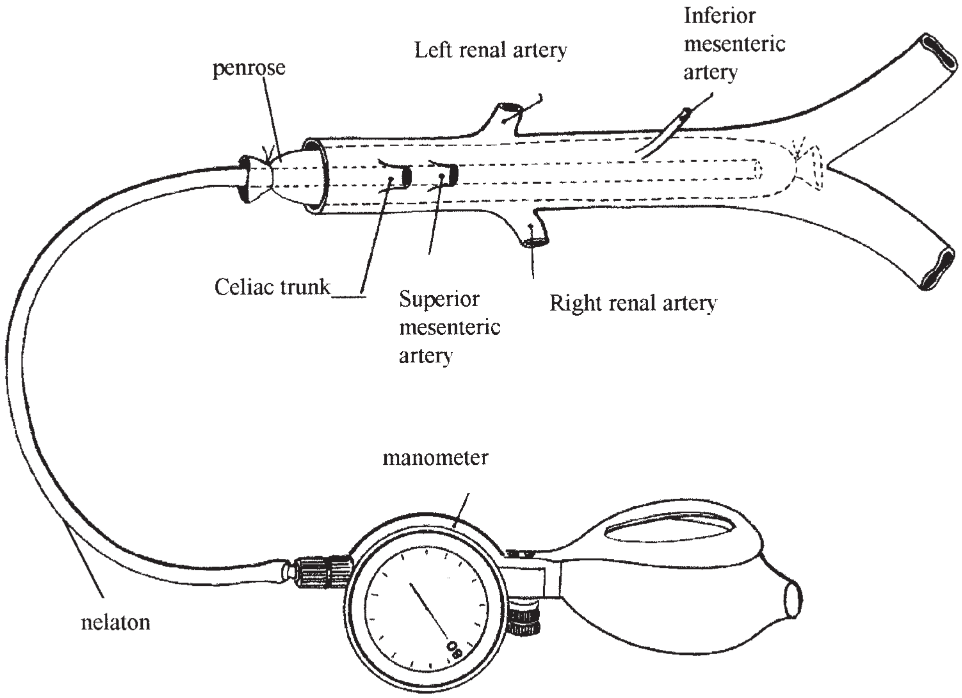


**Fig 1.** Drawing of the distension device inside the aorta.

The population sample investigated was random; ie, the research team would choose some weekdays to conduct the study, during which all corpses of those older than 19 years had their aortas dissected and measured (there was no selection based on sex, race, or disease).

In accordance with age, sex, body length, and presence or absence of illnesses such as arterial hypertension, coronary artery disease, chronic obstructive pulmonary disease (COPD), and sclerosis of the aorta wall, variations in the diameter were analyzed within the group of subjects who did not present anomalies, such as ectasis, arteriomegaly, and aneurysm.

Those subjects who had clinical reports of ailments (angina, infarction, or myocardial revascularization, use of medications, previous hospital admission, etc) or evidence of ailments from the autopsy reports (hypertensive myocardiopathy, nephrosclerosis, acute or chronic myocardial infarction, emphysematous lungs) were regarded as hypertensive, coronaryopaths, or carriers of COPD.

Subjects whose death could be confirmed to occur more than 24 hours earlier were not studied. The abdominal aorta, from the celiac trunk to its aortic-iliac bifurcation, was dissected and promptly removed from the corpse, without any chemical or thermal preparation of the vessel.

We designed a device to reestablish aortic diameter and morphology. This device was placed in the artery and inflated to 80 mm Hg, and the largest external diameter of the aorta (at the inferior mesenteric artery level) was then measured with a pachymeter that indicated cm and mm (Fig 1).

The aorta was longitudinally opened after measurement, to evaluate macroscopic, atherosclerotic alterations present in the inner layer of the vessel wall, which were classified according to a scale[10]: I, lipid streaks; II, lipid plaques; III, exulceration, thrombosis, and hemorrhage of the plaque; IV, calcification of the plaque.

Abnormalities related to diameter were classified into categories: 1, aneurysm: localized dilatation, at least 1.5 times the normal proximal diameter of the observed vessel[11]; 2, ectasis: localized dilatation, with diameter smaller than 1.5 times the proximal diameter observed[11]; 3, arteriomegaly: diffuse dilatation of the vessel, associated with arterial tortuosity and elongation[12,13]; 4, hypoplasia: aortic diameter smaller than 1.2 cm (within the age band studied).[14]

Statistical analysis was accomplished at 95% significance level ($P < .05$), according to arithmetical mean, standard deviation, $t$ test for independent variables (Student $t$ test), correlation and correlation coefficients, multiple regression, and three-dimensional graphs.

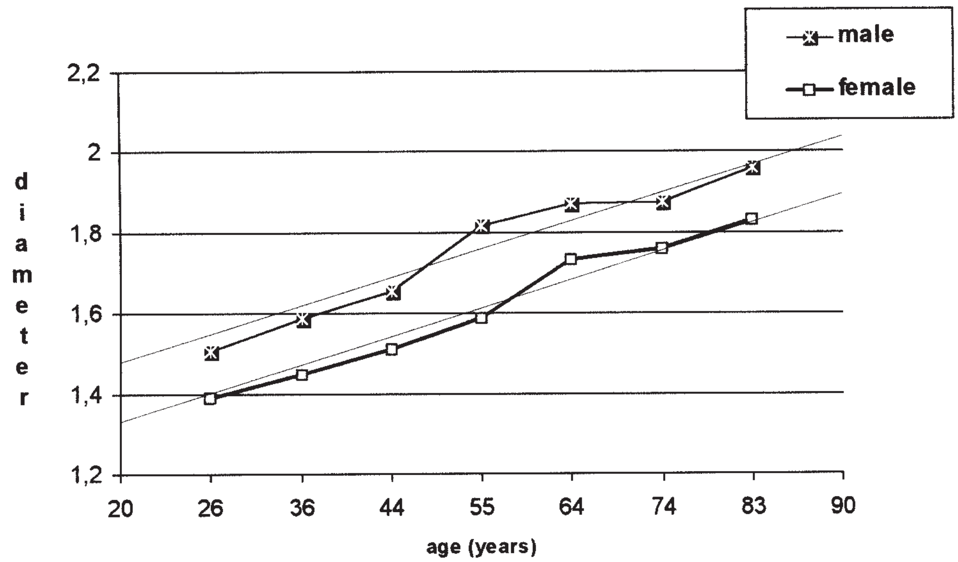


**Fig 2.** Infrarenal aortic diameter according to sex and age. The straight lines represent the linear regression.

**Table I.** Infrarenal aortic diameter according to sex

| *Sex* | *n* | *Diameter* | | | | |
|---|---|---|---|---|---|---|
| | | *Min* | *Max* | *Mean* | *SD* | *Student t* |
| Male | 370 | 1.2 | 2.3 | 1.7492 | 0.2210 | t = 5.5813 |
| Female | 205 | 1.3 | 2.3 | 1.6420 | 0.2201 | $P < .0000001$ |
| Total | 575 | 1.2 | 2.3 | 1.7110 | | |

*SD,* Standard deviation; *min,* minimum; *max,* maximum.

## RESULTS

Of the 645 arteries analyzed, 575 did not have diameter-associated abnormalities. No hypoplasia was observed, but 12 aortas were obstructed, and 29 aneurysms, 19 ectases, and 10 arteriomegalies were found.

The infrarenal abdominal aortas in men displayed larger diameters than those in women, in all age groups studied ($P < .01$; Table I). With aging, aortic diameter enlarged in both sexes. This enlargement occurred in men most often between the fifth and sixth life decades (35% dilation), whereas it occurred most often between the sixth and seventh life decades (33%). The speed of this dilation decreased significantly between the seventh and eighth life decades in both sexes, although a new enlargement started after that period (Table II; Fig 2).

Body size was another variable that influenced the aortic diameter. Subjects with longer body lengths had larger aortic diameters. To demonstrate this finding, we divided the subjects into three age groups (19 to 39 years; 40 to 60 years; and older than 60 years) and into two body-length groups (shorter than 1.70 m; and 1.70 m and longer). The correlation between body length and aortic diameter proved to be positive and significant in men ($P < .01$), but not in women (Table III).

Multiple linear regression allowed us to build a three-variable equation (sex, age, and body length) to obtain the infrarenal aortic diameter (Fig 3).

There were no significant differences between the aortic diameters of control subjects and subjects who were hypertensive, coronaryopaths, or carriers of COPD (Tables IV, V, and VI). Aortas with degree III and IV atherosclerosis had significantly enlarged diameters when compared with those with degree I and II atheriosclerosis ($P < .01$; Table VII).

Diameter-related abnormalities (aneurysms, ectases, and arteriomegalies) are shown in Table VIII. Only four of the 29 aneurysms were rup-

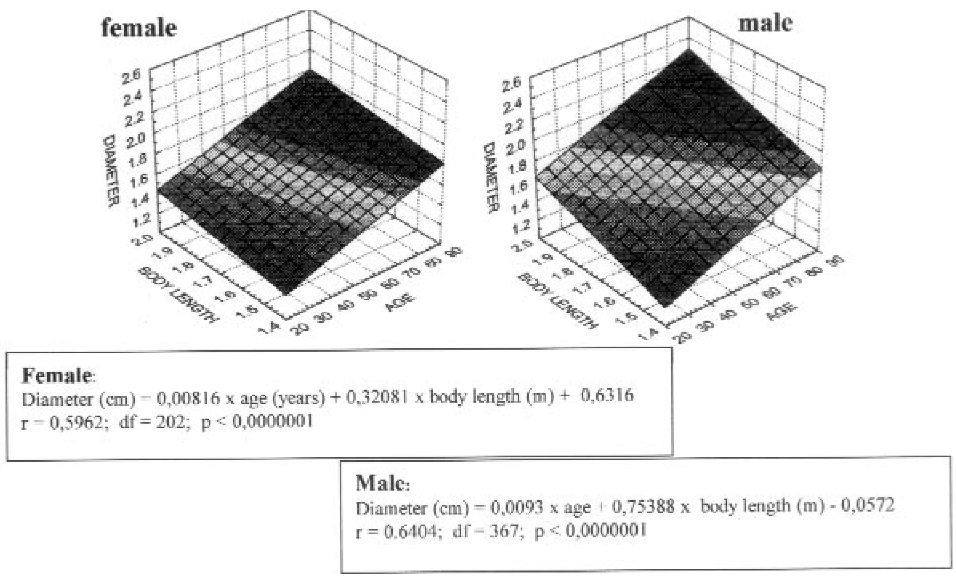


**Fig 3.** Infrarenal aortic diameter according to body length, sex, and age, and the equation for obtaining infrarenal aortic diameter.

**Table II.** Infrarenal aortic diameter according to sex and age groups

| *Sex* | | *Age groups (years)* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *19 - 29* | *30 - 39* | *40 - 49* | *50 - 59* | *60 - 69* | *70 - 79* | *80 - 92* |
| Male | Diameter | 1.5077 | 1.5868 | 1.6568 | 1.8154 | 1.8701 | 1.8763 | 1.9625 |
| | n | 26 | 53 | 88 | 91 | 67 | 38 | 16 |
| Female | Diameter | 1.3889 | 1.4455 | 1.51 | 1.5878 | 1.7311 | 1.7579 | 1.8286 |
| | n | 9 | 22 | 30 | 41 | 45 | 38 | 21 |
| | Student t | 2.74 | 4.36 | 3.57 | 7.15 | 3.81 | 2.46 | 2.09 |
| | Significance | $P < .01$ | $P < .001$ | $P < .001$ | $P < .001$ | $P < .001$ | $P < .02$ | $P < .05$ |

*Diameter,* Mean (cm).

tured, and all occurred in aortas with diameters larger than 5.0 cm.

## DISCUSSION

The infrarenal aortic diameter enlarges with aging, even after body growth has ceased. In addition to age, sex is also a relevant factor, because men show larger aortic diameters than women. The speed of aortic diameter enlargement increases in men between the fifth and sixth life decades, whereas the increase occurs 10 years later in women, between the sixth and seventh life decades (Fig 2). It has been reported that the enlargement of the aortic diameter with aging is caused by deterioration of elastic fibers in the artery wall.[15-17] Our study corroborates the earlier occurrence of deterioration of elastic fibers in men. The speed of diameter enlargement, in both sexes, decreases markedly between the ages of 70 and 80 years.

Body length also influenced the infrarenal aortic diameter of men. This finding was not confirmed in women, probably because of the small number of women in the sample.

Diseases such as arterial hypertension, COPD, and coronariopathy did not influence infrarenal diameter. Comparing (macroscopically) individuals with an advanced degree of arteriosclerosis and those with minor intensity of the disease, it was possible to determine that the first group had larger diameters ($P < .01$).

Because of the clinical selection (a high prevalence of cardiovascular disease [38%] as the cause of death in our study) and demographics (a high number of men [66%] and of white subjects [81%]),

**Table III.** Infrarenal aortic diameter according to body length, age groups, and sex

| *Body length (m) and sex* | | *Age groups (years)* (19 - 39) | (40 - 60) | (>60) |
|---|---|---|---|---|
| ≤ 1.70 | | | | |
| male | Diameter (cm) | 1.483333 | 1.706742 | 1.822807 |
| | n | 24 | 89 | 57 |
| > 1.70 | | | | |
| male | Diameter (cm) | 1.59434 | 1.785106 | 1.95283 |
| | number | 53 | 94 | 53 |
| | Student *t* | 3.16 | 2.76 | 3.52 |
| | Significance | $P < .01$ | $P < .01$ | $P < .001$ |
| ≤ 1.70 | | | | |
| female | Diameter (cm) | 1.41111 | 1.566667 | 1.753333 |
| | number | 27 | 63 | 90 |
| >1.70 | | | | |
| female | Diameter (cm) | 1.55 | 1.6 | 1.8 |
| | number | 4 | 10 | 11 |
| | Student *t* | 1.57 | 0.61 | 0.55 |
| | Significance | NS | NS | NS |

*Diameter,* Mean (cm); *NS,* not significant; *body length,* > 1.70 m or ≤1.70 m.

**Table IV.** Infrarenal aortic diameter and hypertension

| *Sex* | | *Controls* | *CAD* | *Student t* | *Significance* |
|---|---|---|---|---|---|
| Male | Diameter (cm) | 1.7925 | 1.8212 | 0.93 | NS |
| | Age (years) | 57.7 | 57.5 | | |
| | Body length (m) | 1.74 | 1.74 | | |
| | Number | 227 | 66 | | |
| Female | Diameter (cm) | 1.6718 | 1.6964 | 0.72 | NS |
| | Age (years) | 62.5 | 64.9 | | |
| | Body length (m) | 1.66 | 1.65 | | |
| | n | 117 | 57 | | |

*Diameter,* Mean (cm); *age,* mean; *NS,* not significant.

**Table V.** Infrarenal aortic diameter and coronary artery disease (CAD)

| *Sex* | | *Controls* | *CAD* | *Student t* | *Significance* |
|---|---|---|---|---|---|
| Male | Diameter (cm) | 1.8143 | 1.7904 | 0.92 | NS |
| | Age (years) | 58.5 | 57.2 | | |
| | Body length (m) | 1.74 | 1.74 | | |
| | Number | 105 | 188 | | |
| Female | Diameter (cm) | 1.719 | 1.661 | 1.66 | NS |
| | Age (years) | 65.1 | 62.4 | | |
| | Body length (m) | 1.66 | 1.66 | | |
| | n | 58 | 116 | | |

*Diameter,* Mean (cm); *age,* mean; *NS,* not significant.

there is a high prevalence (4.5%) of abdominal aorta aneurysm in our study. The research method used in the work (distension of the aorta wall, prospective nature, individualized definition of aneurysm) also contributed to a larger number of diagnoses. Aorta ectases occurred in 2.9% of the sample, and the method proved to be particularly useful in the detection of these small dilatations. Ten arteriomegaly cases were found in the sample, with two associated dissections. In accordance with the chosen criteria, no hypoplasia case was found.

Previous necropsy studies demonstrated a faster degeneration of elastic fibers on the arterial wall at the fifth decade of life,[18] which coincides with the increased speed of diameter enlargement and is in conformity with the current study in men. A small varia-

**Table VI.** Infrarenal aortic diameter and chronic obstructive pulmonary disease (COPD)

| *Sex* | | *Controls* | *COPD* | *Student t* | *Significance* |
|---|---|---|---|---|---|
| Male | Diameter (cm) | 1.7873 | 1.8419 | 1.78 | NS |
| | Age (years) | 56.5 | 62.2 | | |
| | Body length (m) | 1.75 | 1.73 | | |
| | Number | 231 | 62 | | |
| Female | Diameter (cm) | 1.6778 | 1.69 | 0.26 | NS |
| | Age (years) | 63.6 | 61.9 | | |
| | Body length (m) | 1.66 | 1.66 | | |
| | n | 144 | 30 | | |

*Diameter,* Mean (cm); *age,* mean (cm); *NS,* not significant.

**Table VII.** Infrarenal aortic diameter and atherosclerosis

| | | *Degrees of atherosclerosis* | | | |
|---|---|---|---|---|---|
| *Sex* | | *I and II* | *III and IV* | *Student t* | *Significance* |
| Male | Diameter (cm) | 1.7976 | 1.8738 | 1.78 | $P < .01$ |
| | Age (years) | 60.4 | 62.4 | | |
| | Body length (m) | 1.74 | 1.75 | | |
| | Number | 84 | 149 | | |
| Female | Diameter (cm) | 1.65 | 1.7384 | 0.26 | $P < .001$ |
| | Age (years) | 63.3 | 68.5 | | |
| | Body length (m) | 1.66 | 1.65 | | |
| | n | 64 | 86 | | |

*Diameter,* Mean (cm); *age,* mean; degrees of atherosclerosis: *I, II,* moderate; *III, IV,* advanced.[10]

**Table VIII.** Distribution of aneurysms, ectasia, and arteriomegaly according to age, sex, and diameter

| | *Number* | *Age (mean; years)* | *Sex* | *Diameter (cm)* |
|---|---|---|---|---|
| Aneurysm | 29 | 49 to 97 (69.4) | Male: 22 (75.9%)<br>Female: 7 (24.1%) | < 4.0 cm: 20<br>4.0 to 5.0 cm: 4<br>>5.0 cm: 5<br>2.8 to 9.5 cm: 29 |
| Ectasia | 19 | 42 to 86 (69.2) | Male: 11 (57.9%)<br>Female: 8 (42.1%) | 1.7 to 2.6 cm |
| Arteriomegaly | 10 | 56 to 85 (73.8) | Male: 9 (90%)<br>Female: 1 (10%) | 2.3 to 2.8 cm |

tion of diameter enlargement between the decades of five and six was reported in computed tomography studies.[6] In our study, this stabilization happened later, between the decades of life of seven and eight. The reasons for this decreased speed of aortic diameter enlargement remain unknown.

Relation between body size and aortic diameter is a controversial matter. Some authors have not found any connection,[5,19] whereas others have shown a direct correlation between corporeal surface and aortic diameter[8,14] and the weight and height of the subjects.[2,19,20] The equation designed to calculate the infrarenal aortic diameter based on sex, age, and body length may have a practical value. Diameter abnormalities have different meanings for different individuals. For instance, a 4-cm aortic aneurysm in a 70-year-old, 1.83-m subject with a calculated, expected, 1.97-cm aortic diameter has a different meaning than the same aneurysm in a 55-year-old, 1.58-m woman with a calculated, expected, 1.58-cm aortic diameter. According to Sterpetti et al,[21] the possibility of rupture increases when the relation between aneurysm diameter and normal diameter of the aorta above the aneurysm is larger.

Arterial hypertension is a relevant factor on the dilatation genesis of the ascending aorta,[4] but it has a secondary role in the abdominal aorta (for aortic dilatation in the presence of this disease, a structural defect on the artery wall must exist). COPD also has a secondary role, because we found no differences in the aortic diameters of subjects who were sick and control subjects.

Some authors have shown that the degree sclerosis of the arterial wall has no influence on its diameter,[22-24] whereas others believe that the larger the degree of atherosclerosis, the larger the artery's diameter.[4,25,26] Two hypotheses may explain these findings. First, the intense lesion of the intima layer of the arterial wall may lead to atrophy of the median layer and to secondary dilation of the wall. Second, wider arteries are more rigid, predisposing them to a more turbulent blood flux and more intense formation of atheroma plaques (lesion of the intima layer would then be secondary).

Necropsy studies are important sources of knowledge about two aspects associated with aneurysms, their prevalence and their natural evolution.[27-31] Determination of the diameter of aneurysms (the most accurate possible) is essential for a correct analysis of their natural evolution. Studies performed with the aid of computed tomography, ultrasonography, and surgical measurements of the diameters of aneurysms present discordances.[32-34] Necropsy studies are limited, because the diameter measurement is underestimated because of the aorta's postmortem emptiness. Some authors have demonstrated that the aorta radius doubles when the arterial wall is distended from 0 to a diastolic value.[35] The relevance of distending the aorta artery is also shown by means of diameter enlargement curves versus increase of arterial pressure.[9] Other authors have reported a reduction of even 0.5 cm in the aneurysm's diameter after aortic clamping is applied, viewing their correction.[36] These data suggest that some necropsy studies might supply incorrect information when the aorta is not distended, ie, when the radius of a ruptured, small aneurysm would have been larger than that reported if the aorta were distended.

With their increased prevalence in patients with cardiovascular diseases, ectases are important findings, because they are preaneurysmal dilatations.

Some authors ascribe clinical importance to arteriomegalies.[13,37] Patients who have this condition might sustain intermittent claudication not associated with arterial obstruction, but actually caused by slow sanguineous flux through a diffusely dilated vessel. Atheroembolism, aortic dissection, and aneurysms of iliac arteries may be associated with this clinical condition.[37] Dissection of the ascending aorta associated with arteriomegaly of the abdominal aorta was shown as the cause of death in two of our subjects.

There are various causes of aortic hypoplasia, such as nonspecific aortoarteritis, radiotherapy, tuberculosis, congenital rubella, and congenital hypoplasia.[38] The definition based in arteriography may be inaccurate, because a thickening of the aortic wall will be wrongly estimated. In this study, no aorta with a diameter smaller than 1.2 cm could be found.

Despite the rapid and great technological advances in diagnostic methods, necropsy studies are still important, particularly in the analysis of morphological and structural alterations of organs and tissues. Limitations of postmortem analysis must be overcome, so that its findings can be compared with data obtained from live subjects. The methodology of this study allowed analysis of the infrarenal aortic diameter of an expressive sample of subjects. Some of the information attained does have clinical applicability. First, the contribution to the study of the natural evolution of aneurysms, which demonstrated that small aneurysms did not rupture (24 patients died with intact aneurysms smaller than 5.0 cm; this is an indication that treatment of these patients has to be selective about diameter). Second, the infrarenal, aortic diameter anomalies occur in a population with other affections of the cardiocirculatory system that lead to death. Third, knowledge of the normal diameter expected in a population is also clinically important, because when a patient has larger or smaller diameters, it may explain phenomena such as atheroembolism, dissection, and arterial thrombosis. Likewise, it helps select patients for control of anomalous dilatation.

## CONCLUSION

The diameter of the infrarenal aorta is larger in men, and the abdominal aorta widens earlier in men. Aortic diameter varies according to the body length. In individuals of the same age, sex, and body length, there is a direct relation between sclerotic degree of aortic wall and aortic diameter. Associated diseases, such as COPD, arterial hypertension, and coronariopathy, did not determine differences in the aortic diameter. There was a high prevalence of aneurysms of the infrarenal, abdominal aorta in the sample (taking into account that the sample also included youngsters [age range, 19 to 40 years] and women). Despite the small, absolute number of aneurysms, there were no ruptures found in the aneurysms with a diameter smaller than 5.0 cm.

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